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II. *Observations on Light, and the Waste of Matter in the Sun and fixt Stars, occasioned by the constant Efflux of Light from them : with a Conjecture, proposed by Way of Query, and suggesting a Mean, by which their several Systems might be preserved from the Disorder and final Ruin, to which they seem liable by that Waste of Matter, and by the Law of Gravitation.*

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HAVING in a preceding memoir laid before the Academy the observations, that occurred on the subject of Dr. Franklin's hypothesis relative to light, I shall now consider his objections to the received doctrine concerning it.

The objections will appear by the following paragraph taken from one of his letters on philosophical subjects.

“ I must own, says the Doctor,* I am much in the dark about light. I am not satisfied with the doctrine, that supposes particles of matter called light, continually driven off from the sun's surface, with a swiftness so prodigious ! Must not the smallest particle conceivable have, with such a motion, a force exceeding that of a twenty-four pounder, discharged from a can-

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* See Letters and Papers on Philosophical Subjects. p. 264. edit. 1769.

Just as these memoirs were going to the press, an ingenious gentleman of the American Academy, favoured me with the Philosophical Transactions for 1770, (the 60th vol.) in which the Rev. Dr. Horsley, in a paper entitled, “ Difficulties in the Newtonian Theory of Light, considered and removed,” quotes this passage from Dr. Franklin's letters ; and very ingeniously discusses the questions contained in it.

The subject being considered in that paper, upon principles different from those adopted in this memoir, there will not be found any similitude between them.

non ? Must not the sun diminish exceedingly by such a waste of matter ? and the planets, instead of drawing nearer to him, as some have feared, recede to greater distances through the lessened attraction ? Yet these particles, with this amazing motion, will not drive before them, or remove, the least and lightest dust they meet with : and the sun, for aught we know, continues of his ancient dimensions ; and his attendants move in their ancient orbits."

The Doctor's dissatisfaction with the received doctrine, is founded on two objections implied in his queries, and which may be expressed in the following propositions.

1°. That, supposing the doctrine true, the smallest particle of light must be driven to us with prodigious force, a force exceeding that of a twenty-four pounder, discharged from a cannon. But this is contrary to fact.

2°. That the sun must be exceedingly diminished by such a waste of matter ; and the planets, in consequence of it, must recede to greater distances from him. But, for aught we know, both the sun and the planets, continue in their ancient state.

From these propositions it is implicitly inferred, that the doctrine is not well founded.

Among the observations on the second proposition, an hypothesis will be proposed, by way of query, suggesting a mean, whereby the material system, collectively taken, might be preserved from the disorder and ruin, to which they seem liable from causes hinted at in that proposition.

In regard to the objection contained in the first proposition, it adopts the idea, that light, like any other body in motion, will strike with a force proportioned to the degree of its motion : which degree of motion, or the celerity, multiplied by
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the quantity of matter in the body, will, in the result, express its force or momentum.

If, then, we can suppose the quantity of matter in a particle of light to be, not indeed absolutely, but comparatively, 0, its momentum will also be comparatively 0; and it can have, in that case, no visible effect on the smallest particle of dust to remove it.

Let us now consider what reason there is for such a supposition. In order to that, I beg leave to introduce here, a paragraph from one of my letters to Dr. *Franklin*, printed with his letters and papers on philosophical subjects. It runs thus,*

“ The flame of a candle, it is said, may be seen four miles round. The light, diffused through this circle of eight miles diameter, was contained, before it left the candle, within a circle of half an inch diameter. If the density of light, in these circumstances, be as those circles to each other, that is, as the squares of their diameters (or, which is equivalent, if the density decreases as the square of the distance or semi-diameter increases) the candle-light, when come to the eye, will be 1027,709,337,600 times rarer than when it first quitted the half-inch circle. Now the aperture of the eye, through which the light passes, does not exceed one-tenth of an inch diameter, and the portion of the less circle, which corresponds to this small portion of the greater circle, must be proportionably, that is, 1027,709,337,600 times less than one-tenth of an inch: and yet this infinitely small point (if you will allow the expression) affords light enough to make it visible: or rather, affords light sufficient to affect the sight at that distance.”

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* Letters, &c. p. 275.

If the calculation, referred to in that paragraph, be just ; and we should suppose a single particle of light, though incomparably smaller, to be in bigness equal to that point, I would ask, whether the quantity of matter in such a particle would not be small in a greater degree than its velocity, equal to that of the sun's light, would be great ? If so, a particle of light in motion, agreeably to the foregoing supposition, may be here estimated 0, and its momentum not sufficient to remove the lightest dust ; much less to do as much execution as a twenty-four pounder, discharged from a cannon.

It is impossible to calculate the momentum, where the requisite data cannot be had : but supposing the candle-flame equal in bulk to a sphere of half an inch diameter, and to weigh as much as an equal bulk of air, viz. about one thirtieth part of a grain ; though in fact its gravity is incomputably less than that of air : then the square aforesaid will express the proportion, in which the density of the candle-light is diminished at the verge of the greater circle : and the same proportion of one thirtieth of a grain will express the weight of that light at the verge, viz. one 30,831,280,128,000th part of a grain ; which we will consider as the weight of a single particle of the sun's light. If the velocity of light be at the rate of 80,000,000 miles in six minutes, then its velocity will be 222,222 miles, equal to 14,079,985,920 inches, in a second. This number of inches, divided by 30,831,280,128,000, the supposed particles in a grain, will shew the degree of motion required in a body weighing one grain to give it a momentum, equal to that of a particle of light, upon the hypothesis assumed : which motion will be 456 millionth parts of an inch in a second, equal to one inch in 2190 seconds, or thirty six minutes and an half ; and is much
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flower than the hour-hand of a common clock : which, with its greater degree of motion, and much greater quantity of matter, does not give to the smallest bodies, placed in its way, any visible motion.

Precision in this calculation is not aimed at, and the nature of the subject does not admit of it : but it is apprehended, it will appear sufficiently evident from it, that light, even if its velocity were much greater than it is, and its gravity equal to that of air, to which, with great disadvantage to the argument, it has been, in that respect, compared, cannot drive before it the lightest dust, or, indeed, give it any sensible motion at all.

To the same purpose it may be further observed, that light reflected to the eye through a microscope and prism, would, it is apprehended, exhibit the same variety of colours, as light coming directly from the sun. In which case, the ray so viewed, (like the candle-ray, which has been considered as a single particle only) must be composed of a multitude of particles ; and be a proof, that the particles of light are inconceivably smaller than the calculation supposes. This degree of smallness, however, represents them to be of great magnitude, compared with their real size : for when we consider, that the sun's light is diffused through the whole solar system, and much beyond it ; and that a part of it, in that attenuated state, is reflected to us from the planets, in which reflection it undergoes, by its divergence, a further, and an extreme, attenuation : and especially when we consider the immense sphere, throughout which the light of the fixed stars is visible, particularly those of them, whose distance is so vast, that, at opposite points of the earth's orbit, they have no sensible parallax—the divisibility of light, and the proportionable tenuity of its particles, confound
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the imagination ; and render human calculation inadequate to express the precise degree of them, or the inconsiderableness of the momentum of those particles.

This inadequateness is particularly applicable to the foregoing calculation : which was purposely made on the disadvantageous principles assumed in it, to shew, that even on such principles, the momentum of light could produce no visible motion in the smallest bodies, that fall under our notice. But had the calculation been founded on the state of the sun's light reflected from one of the planets, for instance, the Georgium Sidus, lately discovered by Mr. *Herschell*, the result would have been widely different ; and we should, in that case, have had a juster idea of the momentum. The light reflected to the earth from that planet, whose mean distance from the sun is said to be 5,000,000,000 miles, is so extremely attenuated, that the momentum of a particle of it, transferred to a body, weighing a millionth part of a grain, would communicate to it so small a degree of motion, that it would require millions of ages for that body to move the diminutive part of an inch mentioned in that calculation.

If these observations be just, it is apprehended they shew, with some degree of evidence, that a particle of light, notwithstanding its prodigious velocity, cannot by its impulse remove other bodies, or displace even the finest microscopic dust ; and that the doctrine objected to, may be true, notwithstanding the the first of the two objections, which have been made to it.

The second proposition, containing the other objection, is, that in case there are particles of matter, called light, continually driven off from the sun's surface, the sun must be exceedingly diminished by such a waste of matter ; and the planets,

nets, in consequence of it, must recede to greater distances from him, through the lessened attraction.

Here I beg leave to observe, that if the material system, in its present form, was not intended by its Creator to be perpetual, then the waste of the sun's matter, and the consequent disorder in the system, arising from the altered state of its gravitation, will only be a proof of that intention ; and not operate against the truth of the doctrine.

That system, like every other, derived from the same original, doubtless has within itself the means of continuing in its present form, until the great and wise purposes of its Author shall be brought into effect, and compleatly answered.

With respect to the solar system, so far as its continuance depends on the sun, it seems calculated, notwithstanding the supposed waste of the sun's matter, to last for many ages : for the sun, by reason of its prodigious bulk, and the divisibility of its matter, must, from its own internal sources, furnish light to the system through a long tract of time, without being sensibly diminished. If those eccentric bodies, called comets, which have been thought intended to recruit the sun's waste of matter, do in fact answer that purpose, provision is then made for the preservation of the system, at least until those bodies shall have all successively fallen into the sun, and been expended. When that shall happen, if there be provided no further means of recruit, the system will begin to decay, and finally be reduced to a chaotic state : from which, like our earth, it may be restored in some new form, to answer the further purposes of the Creator. I mention our earth, as in the *Mosaic* account of it, its original is described in such a manner, as to give us the idea of its having been an old planet, by some means or other

reduced to a chaos ; from which it was renovated, and made suitable for the purposes, to which it has been applied.

There is nothing unreasonable, or improbable, in that idea : and if the earth was so renovated, it may be inferred from analogy, that in case the present system should go to decay, a new one, and perhaps a superior one, would arise from its ruins.

These observations are founded on the idea of the waste of the sun's matter, and its final dissolution, with that of the system depending upon it : whether gradually occasioned by that waste of matter, or more rapidly brought on by the general law of gravitation. In this view of things, the objection does not militate with the doctrine.

But perhaps it may be thought more philosophical, and that it would better comport with our ideas of the wisdom of the Creator to suppose, that when he created the system, he intended it should be a permanent one ; and at the same time furnished it with the means of its own preservation. In which case, may it not be further supposed, particularly with regard to the efflux of light from the sun, by which its matter is conceived to be wasted, that he provided means, whereby the effluent particles, after answering the purpose of their efflux, should be returned to the sun, to answer again, in a constant succession, the same purpose.

I do not know, whether the hypothesis, suggested in the following queries, and relative to that subject, be admissible, or not. It is however offered for consideration.

It was primarily and specially intended to suggest a mean for preventing the ruin, to which the material system seems liable from the general principle of gravitation : but the same mean may possibly be applied to restore to the sun, in a regular succession

cession, its effluent light ; and thereby obviate the evil effects, that might otherwise follow from the efflux.

Is it not conceivable, that round the solar system, and the several systems, which compose the visible heavens, there might have been formed a hollow sphere, or orb, made of matter *sui generis*, or of matter like that of the planets, and surrounding the whole : having its inner or concave surface at a proper distance therefrom ; beyond which surface light could not pass, and between which, and the particles of light, there should be a mutual repulsion ? And might not the sun, or source of light, of each system, have been so placed, in respect of each other, and the concave surface of the surrounding orb, that there should be, by direct and repeatedly indirect reflections, an interchange of rays between them, in such a manner, as that to each there should be restored the quantity it had emitted ; and thereby the waste of its matter be prevented : and this at the same time it dispensed its light to its particular system ?

This use of such an orb is here meant to be considered as a secondary or incidental one ; to which it might be applied : but the principal or primary use of it, as a counter-balance to the gravitating principle of the systems contained within it, will be seen in its proper place.

There is a remarkable phenomenon in the solar system, to which the ideal one, just mentioned, bears some resemblance, and by which it was suggested : I mean the ring or arch, which surrounds the planet Saturn. We are told by astronomers, that its width, and also its distance from Saturn, is about 25,000 miles ;—forming around that planet a beautiful arch, which may be designed, among other purposes, to increase its light and heat, by reflecting upon it, like a concave mirror, the sun's

rays : of which, by reason of its great distance from the sun, it would not otherwise have had a sufficient quantity.

If Saturn were a luminous body *per se*, and the arch, (made of suitable matter, and properly constructed, for the purpose) entirely environed it, the whole quantity of light emitted from it, would be reflected back ; and no waste of its matter arise from that emission. The same kind of hollow sphere or orb, surrounding, for instance, the solar system, would answer the same purpose. Its sun, being in the centre of the orb, would have all its light reverberated back to it : except the comparatively small quantity intercepted by the planets : a great part of which quantity would, by direct, and indirect reflections, be returned to the sun ; and a quantity equal to the remainder, by means of volcanoes, and other internal fires in the planets, might be thrown off from them, and conveyed to the sun : whereby the equilibrium of the whole might be preserved.

Such an orb for a single system appears simple and plain ; and such an one for the whole choir of systems, though seemingly more complicated, might yet appear equally suitable for the purpose, when its structure, and the laws and principles which governed it, and also the situation of the several systems relative to it, and to each other, should become known.

Its stupendous extension would be no objection to the supposition of its reality : for if the convenience and pleasure of the inhabitants of Saturn were a sufficient reason for furnishing that planet with its massy ring, the preservation of such a choir of systems, with the astonishing multitudes of their inhabitants, would justify and sufficiently support the supposition of such an orb : especially when it is considered, that besides answering the grand purpose of preserving those systems, it might, per-
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haps like Saturn's ring, be provided on both sides of it, with ample means of making it a suitable place for habitation : the habitation of myriads of millions of animate beings, equal or superior to those, which people our planetary system.

Beyond that orb, at proper distances, it is conceivable, there might be other concentric orbs, equally suitable for habitation, and alike inhabited : including within them innumerable systems of planets, resembling the solar system, and like that animated, and adorning the infinite expanse.

To this hypothesis objections may be made, and such as might prove it to be, like many an one which has preceded it, a mere philosophical revery. But before it be ranked in that class, I would ask, whether, if there be no such orb, nor any thing to answer a like purpose, the law of gravitation, that universal law, on which the philosophy of the immortal *Newton* is founded ; by which, with such admirable sagacity, he has explained the phenomena of material nature ; and on which he makes its preservation depend, will not finally bring on its dissolution ? Or rather, whether the operation of that law would not long ago have brought it on ?

The sun of our planetary system, and the suns (called fixt stars) of other systems, and therefore the systems themselves, do probably, according to astronomical observations, possess the same relative place ; or are, in respect of each other, fixt. But how are the exterior systems (supposing the whole not boundless) prevented from approaching towards the common centre of gravity : from which, if they have no revolution round it, (which the like observations make probable) they cannot be kept by a projectile or centrifugal force ? Must they not constantly by that law be drawn, with an accelerating motion,

tion, towards that centre ; and finally, with the whole choir of systems, directed by that law, arrive at it with successive tremendous crashes, until the destruction of the whole would be completed ? And could any thing but the interposition of the Power which created them, prevent it ?*

If such a catastrophe would be the effect of that law, would it not demonstrate the wisdom, and foresight of the Creator, to suppose, he provided the means of counteracting that effect at the same time he ordained the law ? And among the possible means of doing it, is it not conceivable, that a hollow sphere or orb, analogous to that above-described, might be one ?

It has been suggested in what way such an orb might prevent the gradual waste and decay of the material system. Let us now see, whether it might not be applied to prevent the swifter and more dreadful catastrophe, to which the law of gravitation, in certain circumstances, seems capable of subjecting that system.

The described orb, like every other body, would possess the gravitating principle, in proportion to its quantity of matter : which, in different parts of the orb, might be more or less dense, as the effect, intended to be produced, might require. Where a strong attractive power might be necessary, the density would be greater ; and so, *vice versa* : and to assist or co-operate with it, a magnetic power might be superadded.

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* Mr. *Whiston* observes, “ It is by no means impossible, that all the bodies in the universe should approach to one another, and at last unite in the common centre of gravity of the entire system : nay, from the universality of the law of gravitation, and the finiteness of the world, in length of time, except a miraculous power interpose and prevent it, it must really happen.” *Discourse introductory to his Theory.* p. 38.

Thus constituted, and furnished with those, and other needful qualities, and surrounding the whole visible choir of systems, might not the orb, by the principle of gravitation, either alone or assisted, keep those systems next to it, from being drawn towards the centre of gravity by their own, and the mutual action of the interior systems? And might not those several systems be so placed, and the densities of the bodies respectively belonging to them, with the densities of the surrounding orb, and consequently their mutual gravitating power, be so regulated, and adjusted, as to keep them all at the distance assigned them; and forever prevent their approximating, either to the centre of the general system, or to its surrounding orb: all of them together thus constituting an undecaying permanent whole?

It has been observed by philosophers, “that a body placed any where, within a hollow sphere, which is homogeneous, and every where of the same thickness, will have no gravity, wheresoever it be placed: the opposite gravities always precisely destroying each other.”* But that observation cannot be applied to the hollow sphere or orb, above-described: for by the description, it is not homogeneous.—Nor need it be of equal thickness: which, however, is a circumstance of no consideration, if equal thickness, with different degrees of density in different parts, would answer the purpose.

The phenomena of nature, upon the supposition of such an orb, would probably be the same, *cæteris paribus*, as now take place. Whether that supposition be supported by phenomena, and what other foundation there is for it, will be the subject of a future memoir.

* *Chambers's Cyclopædia*, under the word Gravity.

